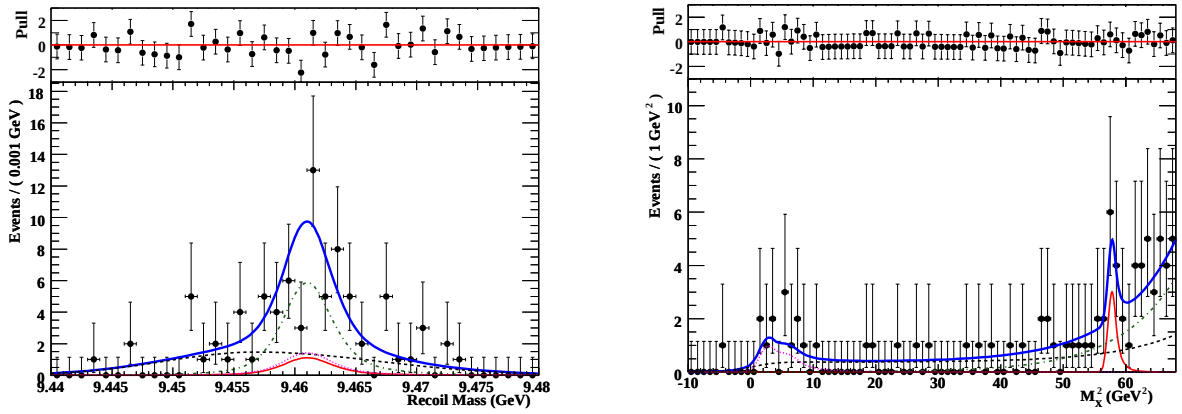
Search for Production of Invisible Final States in Single-Photon Decays of $\Upsilon(1S)$

The *BABAR* Collaboration

The following includes supplementary material for the Electronic Physics Auxiliary Publication Service.



(a) (b)

FIG. 1: Projection plots from the fit with $m_{A^0} = 7.58$ GeV (the most significant deviation from zero) to (a) $M_{\rm recoil}$ and (b) M_X^2. Overlaid is the fit (solid blue line), signal contribution (solid red line), continuum background (black dashed line), radiative leptonic $\Upsilon(1S)$ decays (green dash-dotted line), and radiative hadronic $\Upsilon(1S)$ decays (magenta dotted line). The top plot show residuals in each bin, normalized by the bin error. The fit corresponds to $\mathcal{B}(\Upsilon(1S) \to \gamma A^0) \times \mathcal{B}(A^0 \to \text{invisible}) = (3.2^{+2.2}_{-1.8} \pm 1.0) \times 10^{-6}$, where the first uncertainty is statistical and the second is systematic, and statistical significance of 2.0σ. The probability to observe such a fluctuation *anywhere* in our dataset is over 30%.

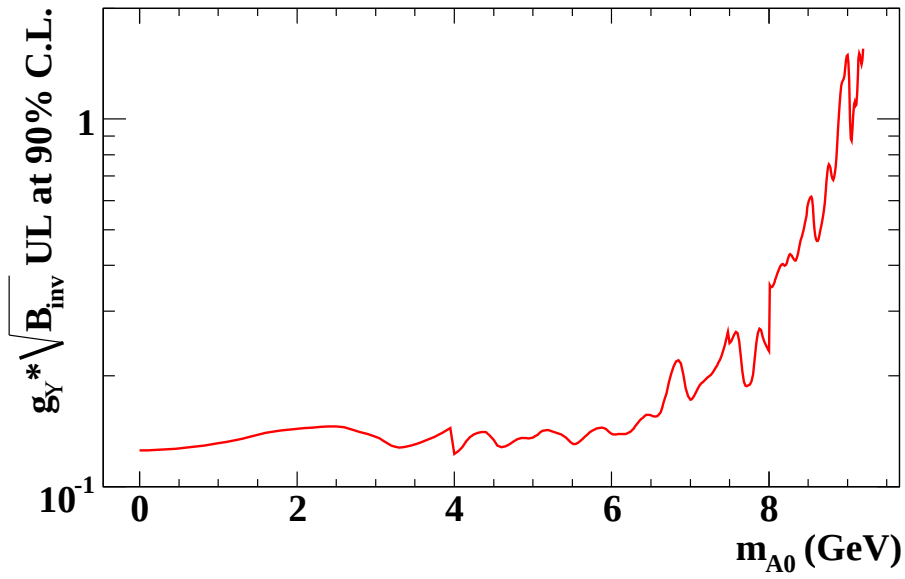


FIG. 2: Upper limits on the product $g_\Upsilon \times \sqrt{\mathcal{B}(A^0 \to \text{invisible})}$ at 90% C.L. as a function of m_{A^0}. The parameter g_Υ is an effective coupling of the CP-odd Higgs A^0 to bound state $\Upsilon(1S)$; in NMSSM, $g_\Upsilon = \tan\beta \cos\theta F_\Upsilon$, where $\cos\theta$ is the fraction of non-singlet component in A^0, $\tan\beta$ is the ratio of Higgs vacuum expectation values, and F_Υ is the effective form-factor (including the QCD and QED corrections). The theoretically preferred region in NMSSM [1] is $g_\Upsilon > 1$.

[1] R. Dermisek, J. F. Gunion, and B. McElrath, Phys. Rev. D **76**, 051105 (2007); R. Dermisek and J. F. Gunion, Phys. Rev. D **81**, 075003 (2010).